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ABSTRACT

This study was concerned with distinguishing between two kinds of immature reasoning, both of which lead children to draw the same conclusions from arguments and which, therefore, cannot be distinguished by the usual tests. A total of 20 second-graders and 16 sixth-graders were tested on a logic game in which winning depended on drawing correct conclusions from logical arguments and on using only the minimum amount of evidence necessary to reach such conclusions. Results indicated that younger subjects drew significantly more conclusions from circumstantial evidence and more often treated logically critical clues as indeterminate. Subjects at both grade levels showed a strong tendency to commit the fallacy of conversion, but older subjects showed improvement in response to feedback. These results support Piagetian stage theory with respect to verbal reasoning. Younger subjects were seen as reasoning in an intuitive, factual manner, while older ones were seen as reasoning from a logical system, albeit a simplified system that erroneously treats conditional statements as reversible. (Author/SB)

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Biconditional versus Factual Reasoning in Children

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Abstract

This study was concerned with distinguishing between two kinds of immature reasoning, both of which lead children to draw the same conclusions from arguments and which therefore cannot be distinguished by the usual tests. Twenty second-grade children and 16 sixth-graders were tested on a logic game in which winning depended on drawing correct conclusions from logical arguments and on using only the minimum amount of evidence necessary to reach such conclusions. Younger subjects drew significantly more conclusions from circumstantial evidence and more often treated logically critical clues as indeterminate. Subjects at both grade levels showed a strong tendency to commit the fallacy of conversion, but older subjects showed improvement in response to feedback. Results supported Piagetian stage theory with respect to verbal reasoning. Younger subjects were seen as reasoning in an intuitive, factual manner, while older ones were seen as reasoning from a logical system, albeit a simplified system that erroneously treats conditional statements as reversible.

Paper presented at Society for Research in Child Development Binennial Meeting, New Orleans, March 17-20, 1977.

Biconditional versus Factual Reasoning in Children[1]

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This study is addressed to a question raised by Ennis (1975):

> What is it that children allegedly cannot do that adolescents can do? Both have ability to reason in accord with at least some of the principles of propositional logic, and both have considerable trouble with logical fallacies. (p. 24)

Ennis is here disputing the idea, suggested by Piagetian theory, that adolescents may be distinguished from children by their ability to handle propositional logic (see, for instance, Inhelder and Piaget, 1958, p. 1). Ennis's claim that children can reason in accord with some principles of propositional logic is in itself not very impressive. The principles that children have been shown to reason in accord with are not the ones that distinguish propositional logic from lower forms of reasoning (Knifong, 1974). Specifically, children have not shown themselves able to carry out reasoning that requires an appreciation of the asymmetrical nature of conditional propositions--that is, an appreciation of the fact that "p implies q" does not mean the same thing as "q implies p" (Shapiro and O'Brien, 1970; Roberge, 1970).

Ennis is alluding to this fact when he says that both children and adults have trouble with logical fallacies. The fallacies at issue take

the form of illegitimate reversals of conditional propositions. The important point is that if the committing of such fallacies is taken as inability to handle propositional logic, then adolescents and adults cannot handle it either (Ennis and Paulus, 1965; Shapiro and O'Brien, 1970; Roberge, 1970; Taplin and Staudenmeyer, 1973). It appears, then, that in order to answer Ennis's question, we must set aside the notion that adolescents are masters of conditional reasoning and must look for distinctions between children and adolescents within the bounds of some lower sorts of logical function.

Knifong (1974; Note 1), drawing on Piagetian theory, has identified two kinds of reasoning, factual and biconditional, that characterize people who have not attained true conditional reasoning.[2] The distinction between these two kinds of reasoning has been suggested by Piaget in lines quoted and translated by Ennis (1975): one must be careful, Piaget says, to distinguish between "that which comes from language and that which language permits the imagination to evoke concretely" (p. 35). Here Piaget seems to be indicating that one may deal with logical arguments in one of two ways. In one way, which is the way of propositional logic, one deals directly with what is said; that is, one operates on the propositions. In the other way, one accepts what is said as factual data, conjures up from it the image of a state of affairs, and then reads off conclusions from this imagined state of affairs. The first way comprises conditional reasoning, but it may also comprise what Knifong (1974) calls biconditional reasoning. The biconditional reasoner reasons by strict logical inference, but he commits fallacies because he treats conditional

statements as if they were reversible. That is the meaning of biconditional; it refers to 'if-then' statements that hold even when antecedent and consequent are reversed. True biconditional statements are often tautologous: "If a ring is costly, then it is expensive." Few assertions are truly biconditional and so the biconditional reasoner, who treats all sentences as if they were, falls into error. For instance, treating the statement "If a ring is made of gold, then it is expensive" as biconditional leads to the mistaken conclusions that if a ring is expensive it must be made of gold and if a ring is not made of gold it must not be expensive.

The second way referred to by Piaget is that of factual reasoning. Given the statement, "If a ring is made of gold, then it is expensive," the factual reasoner might picture a collection of rings, some of which were gold and obviously expensive, the rest of which were cheap rings and not at all golden. From this image the factual reasoner could read off that if a ring is made of gold it is expensive and that if it is not expensive it is not made of gold; but he would also incorrectly read off the conclusions that if a ring is not gold it is not expensive and that if it is expensive it must be of gold. In other words, the factual reasoner draws all the same conclusions as the biconditional reasoner!

Thus, if we go entirely by the kinds of inferences that people draw from propositions, we arrive at an impasse in trying to follow Piaget's injunction. We cannot, in fact, distinguish between "that which comes from language and that which language permits the imagination to evoke concretely." There may, however, be another basis on which factual and biconditional reasoners may be distinguished from each other. The

difference may lie, not in the inferences they draw from arguments, but in what they judge to be conclusive and what they judge to be merely suggestive arguments. Consider the arguments formed by joining each of the following statements to the rule, if it is a sunny day, Joan always goes to the beach.

1. Joan has a cold.
2. It is not a sunny day.
3. It is a sunny day.

To the conditional reasoner (with whom we are not concerned in this study), only the last statement joins with the rule to make a conclusive argument. He realizes that the second statement does not do so, because the rule does not exclude the possibility that Joan also goes to the beach on cloudy days. The biconditional reasoner should believe that both statements 2 and 3 join with the rule to make conclusive (and, of course, contradictory) arguments. Presumably he would recognize that the first statement, although suggestive of a conclusion, is logically irrelevant in the sense that it does not join with the rule to make an argument. It is merely a piece of supplementary information.

But what of the factual reasoner? This kind of reasoner, we must assume, does not think in terms of logical arguments at all, but in terms of images and the linking together of particular ideas. To this kind of thinker, the effect of the given rule should not be to establish a logical premise but to create a picture--an image of a girl romping on a sunny beach, perhaps, along with the contrasting image of the same girl staying inside on a cloudy day.[3] The significance of additional information would

then be judged, not by its logical relevance but by its compatibility with these images. On this basis all three statements would be relevant--the last two obviously so, but the first one also relevant in that it would combine well with the image of Joan staying inside on a dismal day. Furthermore, we might suppose that none of the statements would be altogether conclusive to the factual reasoner. While each would suggest a conclusion, the factual reasoner might find it easy to imagine Joan occasionally going to the beach on cloudy days, staying home on sunny days, and sunning on the beach when she had a cold.

The above speculations suggest several observable differences between factual and biconditional reasoners. On the assumption that factual reasoning characterizes young children and that biconditional reasoning characterizes older children (along with most adolescents and adults), the verification of such differences would go some way toward answering Ennis's question about what it is that adolescents can do that children cannot.

Because it would be difficult to interpret children's statements about conclusiveness, the present study used a game format in which winning depended on drawing correct conclusions from logical arguments and also on using only the minimum of information needed. Information was provided in the form of verbal "clues" like those we have been discussing in connection with the example of Joan and the beach. Two kinds of clues were presented. One kind, which we shall call <u>critical</u>, is represented by both the statement "It is not a sunny day" and the statement "It is a sunny day." These are clues that combine with the

given rule to form an argument--although the argument may be valid or invalid. The other kind of clue, represented by the statement "Joan has a cold," we shall call peripheral. These are clues that provide information related to the topic of the given rule, but they do not combine with the rule to make a coherent argument, whether valid or invalid.

After presentation of a verbal rule, clues were given sequentially. The subject's task was to determine the answer to a yes-no question like "Did Joan go to the beach?" In cases where the critical clue combined with the rule to make a valid argument, the correct answer was that implied by the argument. When the critical clue combined with the rule to make an invalid argument, the correct answer was designated arbitrarily. Subjects could venture an answer any time they were sure of one.

If it is true that younger subjects reason in the factual mode discussed above and that older ones reason according to a biconditional logic, then the following differences should appear:

1. Younger subjects should show less discrimination between critical and peripheral clues. They should show a greater tendency both to draw conclusions from peripheral clues and to seek further information after being presented with critical clues.

2. The response of younger children to critical clues should show evidence of being influenced by preceding peripheral clues. This prediction is made on the assumption that to the factual reasoner the effect of each successive piece of information is to add to or modify his image of a state of affairs. Thus the effect of any clue will depend

on its antecedents. In particular, a critical clue should appear more conclusive if it has been preceded by a clue pointing in the same direction than if it has been preceded by a clue pointing in the opposite direction.

3. On items involving invalid arguments, older children should show more improvement in performance between early and late items. This prediction is made on the assumption that the older, biconditional reasoners will operate according to generalizable logical rules that may be modified in response to disconfirming feedback. Younger, factual reasoners should have little prospect for improvement if, as their label implies, they reason only with the particular facts of each problem. Since the factual content changes from problem to problem, there should be no way for the younger subjects to profit from feedback.

4. Whether they are responding to critical or to peripheral clues, subjects at all ages should draw conclusions that are consistent with the clues given. Thus, if a clue suggests a negative conclusion, that is the conclusion subjects should draw. This prediction mirrors the assumption that factual and biconditional reasoners differ mainly in what they consider to be conclusive information, not in the inferences they draw from given information.

Procedures

Subjects were 20 second-graders and 16 sixth-graders from the University of Toronto's Institute for Child Study School. This school

is not selective, but most of its students come from upper middle-class families. Preadolescents were chosen as the older group so as to have subjects who could be expected to be firmly in command of biconditional reasoning but unlikely to have developed conditional reasoning. Ideally the younger group should have been younger yet, so as still to be at the preoperational stage, to which factual reasoning is most obviously linked. Our previous experience with children and thinking games, however, suggested that children below second grade would be unlikely to grasp the experimental game sufficiently to yield performance data relevant to the hypotheses of the study. The use of second-graders, therefore, represented a practical compromise. It was not expected that they would be purely factual reasoners, but only that they would exhibit more tendencies in that direction than the older subjects.

The vehicle used for testing children's reasoning was a board game in which a marker was moved forward or backward according to the child's success in dealing with a series of 20 logic problems. The board consisted of a series of holes in which a marble, used as marker, could be placed. There were 40 steps from a starting point to the goal, and a number of holes backward from the starting point to allow for adverse fortune.

Each logic problem constituted a step in the game, which was accomplished as follows. The subject was presented with a card on which were printed a rule and question like those illustrated in Table 1. After the rule and question were read aloud to the subject, he was given the first clue. The subject had then to decide whether to answer the question or to take another clue. If he took another clue he had to move the marble back one space. There was then the possibility of taking

a third clue, which would cost another backward move of a space. When the subject answered the question (which was obligatory after the third clue), the problem card was turned over revealing the correct answer--yes or no. If the subject's answer was correct, he moved his marker ahead 4 spaces. If it was incorrect he moved it backwards 3 spaces.

The object of the game was to reach the goal. In introducing the game, it was emphasized to subjects that the only way they could reach the goal was by getting the right answer every time and by never taking any clues they didn't need. They were urged never to answer until they were sure and never to take any additional clues after they were sure. Whenever a subject indicated he knew the answer to a question he was asked whether he was sure and had to confirm that he was before the card would be turned over.

The pay-off rules (4 ahead for correct, 3 back for incorrect, 1 back for another clue) were worked out in pilot testing. Like the age of subjects, they represented a practical compromise. Originally the pay-offs were designed so that impulsive responding would yield zero average progress, but this proved demoralizing to children who found themselves driven backward from the starting point. Accordingly, the pay-offs were adjusted so that subjects were very likely to experience some forward progress, no matter how erratically they performed. This may have reduced the pressure to respond only when absolutely certain of an answer; but it also helped sustain a high level of motivation, which seemed favorable to subjects' adhering to the intent of the game. Two preliminary trials were given to familiarize subjects with the procedure. The first was intended to

trick subjects into responding prematurely, so that they could experience the consequences and acquire a doubting set. The second was an easy item intended to encourage responding as soon as conclusive evidence has been provided. On these items, subjects were shown all three clues and the conclusiveness or inconclusiveness of each clue was explained to them.

The 20 logic problems were generated according to the following specifications. Three principles were tested: the valid principle of detachment, the valid principle of contraposition, and the invalid principle of conversion. A sample problem illustrating each of these principles is given in Table 1. In each problem the critical clue is one that asserts the relevant minor premise--p, not q, or q. Peripheral clues assert none of these, but make some other assertion that suggests but does not logically determine an answer to the problem question. For each of the two valid principles 6 items were generated out of the combinations of 3 positions for the critical clue and two types of logically irrelevant clue (supportive of the critical clue or opposing it). For the invalid principle of conversion, 8 items were generated out of the combinations of 2 positions for the critical clue (first or second), two types of logically irrelevant clue (supportive or opposing) and two answers (yes or no). For these items the third clue afforded a definitive answer to the problem question. In valid principle items the third clue was either the critical clue or a statement of the correct conclusion. In invalid principle items it was always a statement of the correct conclusion, arbitrarily determined of course; since in these items the critical clue does not logically determine an answer, the answer can always be either

yes or no and the subject has no way of telling except to wait for a clue that gives the answer directly.

Within the 20 items, 6 rules were used twice and 8 were used only once. When rules were used twice, one question would refer to the consequent and the other would refer to the antecedent, so as to minimize the possibility of contamination of one item by clues from the other. Furthermore, items with repeated rules were never adjacent in the presentation order and subjects were reminded each time to ignore what was said the other time the rule had appeared.

The 12 valid argument items were presented first, in a randomized order, followed by the 8 invalid argument items, also randomized. Subjects were tested individually. Testing time was about 35 minutes. All information on cards was read aloud to subjects so as to minimize effects of reading ability.

Results

Hypothesis 1 was that younger subjects would show less discrimination between critical and peripheral clues. This hypothesis will be examined separately for items involving valid arguments and those involving invalid arguments, since in the latter case failure to respond to a critical clue is ambiguous--it may indicate failure to recognize the logical argument or it may indicate recognition that the argument is invalid.

On the 12 items involving valid arguments, only two children in the entire sample (both sixth-graders) always responded to the critical clue.

By 'responding' we mean stating an avowedly certain conclusion after being presented a clue. By the more liberal criterion of responding to the critical clue three-fourths of the time, 25 percent of second graders qualified, while 81 percent of sixth-graders did--a significant difference (X^2 with Yates correction = 7.20, d.f. = 1, p .01).

Among the second-graders, 18 of 20 responded early at least once, 17 responded late at least once (that is, took another clue after the critical clue), and 15 responded both early and late at least once. Among the sixth-graders 11 of 16 responded early at least once, 9 responded late at least once, but only 5 did both. This 5 out of 16 differs significantly from the corresponding 15 out of 20 second-graders (X^2 = 5.23, d.f. = 1, $p < .05$). The other frequency differences are not significant.

Considering the average frequency of early and late responses, second-graders responded early on 50 percent of the items where this was possible, compared to 18 percent for sixth-graders (t = 3.59, d.f. = 34, $p < .01$). Second-graders responded late on 19 percent of the items where it was possible, compared to 9 percent for sixth-graders (t = 2.46, $p < .02$). Both groups had a significant bias toward responding early rather than late, but the bias was significantly greater for second-graders. Early responding was not indiscriminate, however, even for second-graders. They responded to the first clue 70 percent of the time when it was a critical clue but only 33 percent of the time when it was a peripheral clue. For sixth-graders the corresponding percentages were 88 and 6.

Items involving invalid arguments showed the same tendency of second-graders to respond before the critical clue was given. They did so on 40 percent of the items where it was possible, compared to 20 percent for the sixth-graders ($t = 1.84$, d.f. = 34, $p < .10$). As for late responding, however, there was scarcely any difference between the groups. Second-graders responded after the critical clue on an average of 19 percent of the items, sixth-graders on 20 percent. Note that for second-graders the rate is exactly the same as with items involving valid arguments; it is the sixth-graders who responded differently, exhibiting a greater frequency of delayed response with invalid argument items ($t = 2.49$, d.f. = 15, $p < .05$).

The second hypothesis was that the response of younger subjects to critical clues would be influenced by preceding peripheral clues. In brief, there was no evidence of such an effect, either with valid argument items or invalid argument items. There was no evidence that preceding clues influenced whether a subject would respond to a critical clue nor how he would respond to it if he did.

The third hypothesis was that on invalid argument items older subjects would show more inter-trial learning than younger ones. For this analysis invalid argument items were scored in two ways. The first, called the conditional reasoning score, counted a response as correct only if it was made to the third clue and was consistent with it. The rationale for this score is that it should reflect a subject's awareness that the critical clues in these items are not validly conclusive. The other way, called the biconditional reasoning score, counted a

response as correct only if it was made to the critical clue and was consistent with it. The rationale for this score is that it credits what would be correct responses if the given rules were biconditional--that is, if it were true that "If p, then q" also meant "If q, then p." A pure biconditional reasoner should thus get a perfect biconditional reasoning score and a zero conditional reasoning score. Learning would be indicated by an increase in conditional reasoning score and probably, but not necessarily, by a decline in biconditional reasoning score.

On these criteria, sixth-graders showed definite evidence of learning. Between the first four invalid argument items and the remaining four, conditional reasoning scores rose from an average of 3 percent to 20 percent ($t = 2.91$, d.f. = 15, $p < .02$). Correspondingly, biconditional reasoning scores declined from 73 percent to 55 percent ($t = 2.42$, d.f. = 15, $p < .02$). There was a correlation of .38 (not significant) between gain in conditional reasoning and decline in biconditional reasoning. Second-graders showed slight and nonsignificant trends of the same kind. Conditional reasoning performance rose from 8 percent to 15 percent correct; biconditional reasoning declined from 58 percent to 56 percent. The two kinds of changes correlated .37 ($p < .10$, d.f. = 19). For the two groups combined, the correlation between gain in conditional reasoning and decline in biconditional reasoning is .40, significant at the .02 level. It should be noted that this correlation may be spurious, since biconditional and conditional reasoning responses cannot co-occur. However, given the incidence of responses that

were neither biconditional nor conditional, the correlation in question could have been zero or even negative.

By contrast, there was no evidence of learning on items involving valid arguments. When scored on the basis of responding correctly to critical clues, second-graders obtained exactly the same percentage right in both halves of the set of items (49 percent). Sixth-graders went from 78 percent right to 80 percent.

The final hypothesis was that subjects at both grade-levels would respond in ways consistent with the given clues, whether the clues were critical or not. Response frequencies bearing on this hypothesis are reported in Table 2. Every clue was designed to have a definite direction to it, to suggest either a yes or a no answer to the problem question. As the first column of Table 2 indicates, the vast majority of all responses were consistent with the direction of the clue just given. Some inconsistent responses might reflect a weighing of clues or a belated decision to go with a preceding clue. These would show up as responses that were inconsistent with the clue just given but consistent with at least one preceding clue. As the second column of Tabel 2 shows, such responses accounted for a very small percentage of all responses.

The remaining, apparently erratic responses, also account for a small percentage of responses, except in the case of second-graders dealing with valid argument items. Here 15 percent of responses were inconsistent with any clue given up to the time of responding. The fact that second-graders performed more consistently on the later, invalid argument items, would suggest a learning effect—perhaps merely

acquiring a better grasp of the nature of the game. This speculation is belied, however, by the fact that almost two-thirds of the second-graders' erratic responses were made to the second half of the set of valid argument items.

One further data analysis was carried out for the purpose of facilitating comparison between the results of this study and other research. A three-way analysis of variance was carried out on performance on valid argument items. Factors were grade level of subjects (second or sixth), position of the critical clue (first, second, or third), and type of argument involved (detachment or contraposition). The dependent variable was number of correct item responses. In order to be scored as correct, a response had to be made to the critical clue and consistent with it.

No effects involving type of argument were significant, so nothing more will be said of that. Figure 1 graphs the two significant main effects. The effect of grade level of subjects was significant at the .001 level ($F = 17.82$, d.f. = 1, 34). The effect of position of the critical clue was also significant at the .001 level ($F = 21.05$, d.f. = 2, 171). As Figure 1 indicates, the tendency was for subjects to perform better when the critical clue came early. No interactions were significant.

Discussion

Four hypotheses were tested, all concerned with a possible difference between the propositional reasoning processes of younger and older children. Two of the hypotheses were strongly supported, one was definitely not

supported, and one is a matter of judgment.

The central, and most strongly supported, hypothesis was that younger subjects would tend not to discriminate between what in this study are called critical and peripheral clues. (Critical clues are minor premises that combine with a major premise to produce a coherent argument, whether valid or invalid. Peripheral clues do not thus combine, but merely add supplementary information related to the topic of the major premise.) The clearest support for the hypothesis comes from those items in which the critical clue combines with the major premise to form a valid argument (as in the first two items in Table 1). On such items, only 25 percent of second-graders showed a consistent tendency to respond to critical clues in arriving at decisions (as demonstrated by doing so at least three-fourths of the time). This is compared to 81 percent of sixth-graders who did so.

It is certainly not true that the younger children showed no discrimination among premises. On valid argument items, they chose to respond to the critical clue an average of 54 percent of the time, while by pure chance they would have done so only 33 percent of the time. But, by contrast, the sixth-graders responded to the critical clue, on average, 82 percent of the time.

In order to interpret these results as showing something about differences in reasoning processes, it is important to know that the younger children are not simply behaving more erratically. This was the point of hypothesis 4, and it is with respect to this hypothesis that the results are a matter of judgment. Subjects' responses to clues, no

matter whether they were responding to critical or to peripheral ones, were consistent with the directional bias of the clues over 90 percent of the time--except in the case of second-graders dealing with valid argument items. Their responses were consistent with the immediately given clues 83 percent of the time, and 15 percent of the time their responses were not consistent with any clue they had been given.

The difference between second-graders and sixth-graders in percentage of consistent answers is not significant ($t = 1.70$, d.f. = 34). A more pertinent question, however, is to what extent the difference in consistency might account for the difference in discrimination of critical clues. To examine this question, we eliminated all subjects who responded inconsistently on more than one of the 12 valid argument items. In this way, half of the second-graders and 3 of the 16 sixth-graders were eliminated. The remaining subjects were then compared as to the frequency with which they responded to critical clues. The remaining second-graders responded to the critical clues on average 67 percent of the time (compared to 54 percent of the time for the entire second-grade group). The remaining sixth-graders responded to the critical clues 83 percent of the time (compared to 82 percent for the entire sixth-grade group). Thus the consistent responders among the second-grade group did respond more to critical clues than their less consistent classmates. But the difference between them and the consistent sixth-graders is still significant ($t = 2.64$, d.f. = 21, $p < .02$). Thus the main point of the first and fourth hypotheses seems to hold up: that it is what clues they

respond to rather than how they respond to them that mainly distinguishes younger from older subjects.

The other supported hypothesis was that older subjects would show evidence of learning on invalid principle items, while younger subjects would not. The basis of this hypothesis was that if the younger subjects reason on a factual basis, there should be no way for the feedback on one item to help them do better on the next. There was no evidence to suggest that any of the older subjects actually 'caught on' to conditional reasoning; but, considering the small number of trials available for learning, there was definite progress in that direction, which is consistent with the idea that these subjects should be in a transitional stage to formal operational thought.

The hypothesis that younger subjects would show a biasing effect of peripheral clues on their response to critical clues received no support. This hypothesis was based on the supposition that factual reasoners would process clues cumulatively, building up an image in much the same way that one does in reading a story or a descriptive passage. That is not what the young subjects in this study seemed to do. Instead, they appeared to deal with each clue separately, waiting for one to come along that made a strong enough impression on them to motivate a decision. This is not very surprising behavior. It is what Bartlett (1958) described as "everyday thinking," and which he found to characterize most adult thinking in forming judgments.

Do these findings add up to an answer to Ennis's question, "What is it that children allegedly cannot do that adolescents can do?" As we indicated at the beginning, we have not been seeking an answer in the form

of some overt capability that would distinguish young from old. Rather, we have sought it in the form of a difference in the way children reason with verbal rules.

In its strongest form, our answer to Ennis would be that what young children cannot do is tell the difference betwen a logical deduction and an intuitive judgment. Compared to the older children, the younger ones in this study showed a strong tendency to treat as equivalent those kinds of statements that formed logical arguments and those that merely contributed circumstantial evidence.

This strong conclusion must immediately be moderated by noting that the observed differences between older and younger were only a matter of degree. The younger children showed a preference for logically critical clues and the older ones were not perfect in their discrimination. However, it was in the nature of the study that all-or-none results could not be expected. For reasons that have been noted, the younger subjects were too old and the older subjects too young to provide the maximum separation in capabilities. The clues were not calibrated in any way that would permit one to say that the critical clues and peripheral clues were equally attractive in their own right. It is pertinent to the results, however, that in designing the peripheral clues we made a special effort not to make them intuitively compelling. For instance, in the first item in Table 1, we would not have used as a peripheral clue, "Joan was in the hospital with a broken leg." Although, within the game of propositional logic, this fact would not stand in the way of Joan's going to the beach, given that it was a sunny day, we could not expect children to brook such

a violation of common sense. And so the peripheral clues tended to be on the weak side, as the sample items show. Accordingly, the fact that younger children showed a preference for critical clues may not mean much. It is only the difference between younger and older subjects that can support interpretation.

Ennis (1975) was challenging the notion of qualitatively different stages in the development of propositional reasoning. The present results are too slender to constitute a demonstration that stages exist. But the results are quite compatible with the overall Piagetian stage theory and seem best explained in that light rather than by an ad hoc explanation. What we seem to have observed are a group of younger children just entering the stage of concrete operations and still showing a good bit of prelogical thinking. Then we have observed an older group at the end of the concrete operational stage and well fixed upon the biconditional reasoning that seems characteristic of that stage, although they show signs of being amenable to instruction that would urge them in the direction of conditional reasoning, characteristic of the next stage.

Our results, it should finally be noted, are not incompatible with those Ennis cited in arriving at a contrary conclusion. Both the older and the younger groups commit the fallacy of conversion, and both show success in handling the valid principles of detachment and contraposition. The findings graphed in Figure 1, however, provide grounds for tempering the statement that children can handle the valid principles. Those items in the present study that have the clue in the first position resemble the items used in other research. The subject is simply presented with

a logical argument and ask to respond to it; no peripheral clues are involved at that point. Performance on those items clearly supports the notion that even the younger children can handle valid arguments to a fair degree: they responded appropriately 59 percent of the time, which is as good as the performances reported by Ennis. But if we look at items where the child has to withstand the temptation of two peripheral clues before getting to the logically critical clue, we see that only 36 percent of the second-graders make it. This suggests that what appears to be propositional reasoning in other research on young children may simply be intuitive responding that happens, in the case of uncontaminated valid arguments, to lead to right answers.

Footnotes

1. The authors wish to thank George Dimitroff and Gloria Roberts for their assistance in conducting the study and Dr. James Fair of the Institute of Child Study, University of Toronto, for his cooperation in providing access to children who took part in the study.

2. Although our distinction between factual and biconditional reasoning owes a debt to Knifong's analysis, our conception of factual reasoning is not the same as his. Knifong treats factual reasoning as equivalent to converting implications into and relationships--that is, converting 'p implies q' into 'p and q.' According to this formulation, the negation of either term should have no necessary effect on a subject's belief in the truth of the other. Knifong correctly observes that this model does not fit the behavior of school age children, from which he concludes that factual reasoning must be confined to children of preschool age. But there is no evidence that the 'p and q' model fits preschool children either, and we cannot imagine it fitting any sensate organism. It seems to us that the model is an inappropriate representation of the childish notion that things 'go together'--which is how Piaget (1928) characterized transductive logic. The more adequate representation is 'p and q or not p and not q'--in commonsense terms, if two things 'go together,' it means either both are present or both are absent. This model is then isomorphic with the biconditional model applicable to older children. And that is why, if a difference between factual and biconditional reasoning exists, it must be found in something other than their logical forms.

3. The words picture and image should not be taken too literally in this account. We mean some kind of mental representation of situations and events, not necessarily visual.

Table 1

Sample Items Illustrating Variations Used in the Study

Item	Type of Clue	Symbolic Representation
1. Valid argument - detachment		
Rule: If it is a sunny day, then Joan will go to the beach.		$p \rightarrow q$
Question: Did Joan go to the beach?		
Clue 1: Joan loves to swim.	Peripheral, supporting	-
Clue 2: Joan has a good suntan.	Peripheral, supporting	-
Clue 3: It was a sunny day.	Critical	p
Answer: Yes.		q
2. Valid argument - contraposition		
Rule: If Tommy plays in the sandbox, then his hands will be dirty.		$p \rightarrow q$
Question: Did Tommy play in the sandbox?		
Clue 1: Tommy's hands were not dirty.	Critical	not q
Clue 2: Tommy's friends came to play in the sandbox.	Peripheral opposed	-
Clue 3: Tommy did not play in the sandbox.	Direct conclusion	not p
Answer: No.		not p
3. Invalid argument - conversion		
Rule: If the birdcage door is open, then Tweety the bird will sing.		$p \rightarrow q$
Question: Was the birdcage door open?		
Clue 1: Tweety's owner likes to leave the birdcage door open.	Peripheral, supporting	-
Clue 2: Tweety the bird was singing.	Critical	q
Clue 3: The birdcage door was not open.	Direct conclusion	not p
Answer: No.		not p

Table 2

Consistency of Responses with Clues Given

	Percentage of item-responses		
	Consistent with immediate clue	Consistent with previous clue	Not consistent with any given clue
Valid Argument Items			
Second-graders	83	2	15
Sixth-graders	93	3	4
Invalid Argument Items			
Second-graders	90	1	9
Sixth-graders	91	4	5

Reference Note

1. Knifong, J.D. A Piagetian analysis of logical abilities of young children. Unpublished manuscript, University of Maryland, undated.

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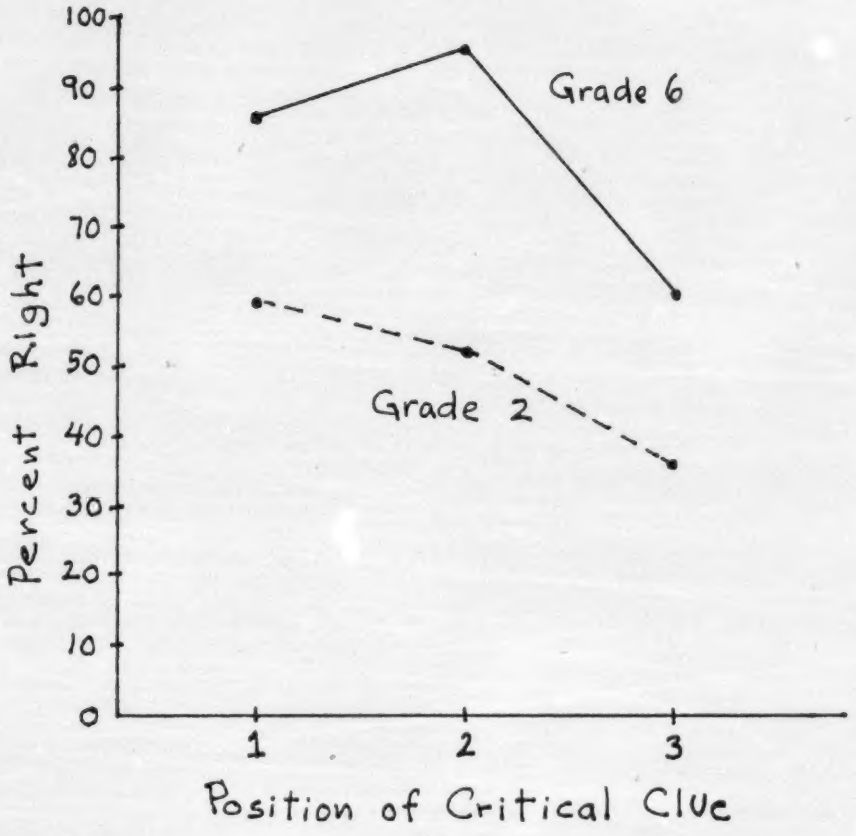

Fig. 1. Percentage of items correct by grade-level of subjects and position of critical clue.